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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements relating to Cigarette Smoking Machines

We, GALLAHER LIMITED, a British Company, of 138 York Street, Belfast, Northern Ireland, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to machines which smoke cigarettes automatically for use in testing the burning rate and qualities of cigarettes and to produce smoke under conditions which are as natural as possible for analysis and animal inhalation experiments.

One type of prior machine consists of a number of tubular cigarette holders carried from a common manifold to which a vacuum can be applied so that in use air is drawn continuously or at intervals through the cigarettes mounted in the holders and into the manifold. This is a convenient way of producing a large quantity of smoke quickly, but the machine is not sufficiently accurate for analytical purposes because the cigarettes are not all smoked in exactly the same controlled manner. For example the pressure drop through the different cigarettes when a puff is taken may well depend upon the relative positions of the different holders carried by the manifold.

When the smoke yield of cigarettes is to be analysed, it is necessary to be able to control the air flow through a cigarette as each puff is taken, the length of time of each puff, and the number of puffs per minute. For example, a standard test which is generally accepted throughout the industry in Britain consists of a puff volume of 25 ml, and a puff time of 2 seconds at a rate of one puff per minute, the cigarettes being smoked down to a predetermined butt length. A known machine which will smoke cigarettes under these accurately defined conditions consists of a number of static cigarette holders each coupled through a separate electro-magnetically operated valve to a source of vacuum, the vacuum pressure and the opening and closing of the valves being controllable. Since a separate valve is required for each holder, the machine tends to be bulky and complex and impossibly so if enough holders are to be provided to smoke a large number of cigarettes, for large scale tests or for producing bulk quantities of smoke condensate for analysis.

In order to try to overcome the difficulty of smoking a large number of cigarettes simultaneously and under analytical conditions, a machine has previously been developed consisting of a rotary smoking head which is rotated in stepwise manner about a horizontal axis against a vacuum port through which vacuum is applied. A number of cigarette holders extend axially from the head in a common vertical plane and as the head rotates the holders move successively into communication with the vacuum port so that puffs are successively taken through cigarettes mounted in the holders. Between puffs the cigarettes remain smouldering. This machine, although overcoming some of the previous disadvantages, is unsatisfactory in that as the head indexes through each step to bring the next holder into register with the vacuum port, after each puff the cigarettes are subjected to a rapid acceleration which influences the burning rate, and also disturbs the natural smouldering of the other cigarettes. The smoke rising by convection from the cigarettes in the holders at any time at the bottom of the smoking head rises past the smouldering cigarettes at a higher level and consequently the cigarettes at the higher level burn in an

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atmosphere which is unnaturally hot and smokey and furthermore the cigarettes are not smoked in an atmosphere of pure air but rather in a warm atmosphere contaminated with side stream smoke of different composition to normal smoke.

In accordance with this invention a cigarette smoking machine comprises a smoking head which is provided with a ring of cigarette holders for supporting cigarettes so that they extend substantially radially outwards from the head and which is continuously rotated about a vertical axis to bring a series of smoke ducts in the head, one in communication with the interior of each holder, into register with a vacuum port to which vacuum can be applied to draw a puff of air through each cigarette mounted in the holders in turn.

With this arrangement since the holders are arranged so that the cigarettes will substantially extend outwards in a radial plane, the smoke and heat from one cigarette cannot interfere appreciably with the combustion of other cigarettes. Furthermore, since the head rotates continuously, the cigarettes are not jerked.

Preferably the smoke ducts all open into an annular surface of the head, this surface sweeping over a stationary slide surface in which the vacuum port is formed. The machine may also include a butt ejecting mechanism comprising a secondary stationary slide surface over which the annular surface sweeps and which is formed with a pressure port, the pressure port being successively brought into communication with the smoke ducts and being arranged in use to be supplied with pulses of air pressure whereby the butts of burnt cigarettes can be ejected from the holders by air pressure pulses applied to the corresponding smoke ducts through the pressure port. In this case the butt ejecting mechanism preferably also includes a butt length sensing element which is mounted adjacent to the ring of holders and which responds to a passing cigarette butt if the cigarette has burnt down to a predetermined butt length, the element then triggering means for supplying a pulse of air pressure to the pressure port when the smoke duct leading to the holder carrying that cigarette butt is next in communication with the pressure port so that the cigarette butt is ejected from its holder. The advantage of ejecting a burnt cigarette butt after it has burnt down to a predetermined length, rather than after a predetermined number of puffs have been taken, is that it ensures that the procedure approximates as nearly as possible to human smoking.

The head preferably rotates over a chamber in which the vacuum port is provided, the smoke ducts opening into the chamber through substantially the whole of the period in which they are not in communication with a vacuum port, or with the pressure port when one is provided.

Although a vacuum may be applied to the vacuum port, of a machine incorporating the above described main features of the invention, continuously so that a puff is taken whenever any part of one of the smoke ducts is in communication with a vacuum port, this is generally less flexible and involves the use of very accurately machined parts. The vacuum supplied to the vacuum port is therefore preferably controlled so that it is only applied during a period in which a constant cross-sectional area of smoke duct is in communication with a constant area of the vacuum port. For this purpose the outlet ends of the smoke ducts or, preferably, the vacuum port, are or is elongated in the direction of relative movement between the head and vacuum port so that a constant area of one will be in communication with a constant area of the other throughout the period in which the puff is taken. In this way the puff flow profile corresponds to the generally accepted pattern, of sharp vacuum cut on and cut off, for cigarette smoking machines. Even so, only one valve is required as only one vacuum supply to the common vacuum port is necessary. This has a decided advantage over machines incorporating a number of magnetic valves as it is not subject to varying errors between smoking ports caused by the variation in the response times, dead times, rise time, and flow capacities of pneumatic valves.

If the machine is intended for use for the standard test of making two second puffs at a rate of one per minute, at least 25 cigarette holders may be mounted on a head enabling approximately 150 cigarettes to be individually smoked under strict analytical conditions each hour. The machine may of course have a number of heads in tiers but if so they should be of different radius so that the smoke rising from the lower tiers will not effect the combustion of cigarettes carried by the upper tiers.

When the vacuum is applied to the vacuum port for a succession of preset periods, for example 2 seconds, during each puff cycle of the head, it is important that these period should be timed accurately to coincide with the period during which the constant areas of the smoke ducts are in communication with a constant area of a vacuum port. The timing may be controlled by means of snap action cams which are rotated synchronously with the smoking head and control the opening and closing of a valve in a conduit through which vacuum is applied to the vacuum port.

A machine incorporating the above mentioned main features of the invention may be adapted for use in carrying out animal inhalation experiments. For this purpose the machine may be further provided with a ring

of animal cages which rotate with the head, a series of gas ducts leading one to each cage, and a gas distribution system which is arranged to supply a vacuum to the vacuum port to draw puffs of smoke through the cigarette holders in turn and to distribute the smoke to the gas ducts. Since the cages rotate with the smoking head, this arrangement enables mice or other animals in the cages to be fed with fresh substantially unaged smoke in a very compact manner.

In order that comparative experiments may be made between smoke and other polluted gases, such as air polluted with dust or chemical aerosols, the gas distribution system is preferably selectively capable of distributing other gases instead of or in addition to smoke through the gas ducts. In this way animals in the cages can be forced to inhale pure smoke, that is "direct smoking", or a mixture of smoke diluted with air, that is "indirect smoking". Alternatively gas borne aerosols of liquid chemicals or dust particles can be fed to the animals.

Preferably the gas ducts will open into an annular surface of the head which sweeps over a stationary gas distribution slide surface formed with at least one gas port to which the gas distribution system distributes the smoke or other gases and which is successively brought into communication with the gas ducts in turn. Provision may also be made for withdrawing from the animal cages inhalations previously fed to the cages through the gas ducts. For example a number of exhaust ducts may lead one from each cage and open into an annular surface of the head which sweeps over a stationary gas distribution slide surface formed with at least one exhaust port to which the gas distribution system selectively provides a suction and which is successively brought into communication with the exhaust ducts to draw smoke or other gases from the cages in turn. Most simply the at least one gas port and the at least one exhaust port, each in the form of a circumferentially extending slot, are formed in a common gas distribution slide surface. The annular extent of the circumferentially extending slots determines the duration of feed of smoke or other gases to the cage and exhaustion of the cages.

Two examples of smoking machines constructed in accordance with the present invention are illustrated in the accompanying drawings in which:

Figure 1 is a plan, with some parts omitted, of the first example;

Figure 2 is a detailed elevation as seen along the arrow II;

Figure 3 is a section, with some parts omitted, and taken on the line III—III in Figure 1;

Figure 4 is a detailed elevation as seen along the arrow IV in Figure 1;

Figure 5 is a schematic elevation as seen along the arrow V in Figure 1;

Figure 6 is a diagram of the vacuum circuit of the machine;

Figure 7 is a diagram of an electronic control circuit which controls the automatic recharging of the machine with cigarettes;

Figure 8 is a plan with parts omitted of the second example;

Figure 9 is a section taken on the line IX—IX in Figure 8;

Figure 10 is a perspective scrap view of a cigarette butt length sensing device;

Figure 11 is a view similar to Figure 10 but during a later stage in the operation of the device;

Figure 12 is a scrap section taken on the line XII—XII in Figure 8;

Figure 13 is a scrap section taken on the line XIII—XIII in Figure 8;

Figure 14 is part elevation, part section taken on the line XIV—XIV in Figure 8, showing a cigarette charging mechanism; and,

Figure 15 is a circuit diagram illustrating the operation of the machine.

The first machine illustrated in Figures 1 to 7 comprises a cylindrical chamber 16 which is mounted on legs 17 and has a close fitting cover 18 which forms the smoking head. The chamber 16 may be provided with a drain opening for use in swilling out the chamber. The head 18 supports twenty five equiangularly spaced cigarette holders 19 by means of individual tubular necks 20 which are curved so that the holders 19 overlie an annular ashtray 21. Each of the holders 19 includes a pair of annular flexible rubber discs 22 which are separated by spacers 23, the discs and spacers being retained within the holder 19 by a chamfered throat piece 24 which is screwed into the holder. A cigarette 25 may be pushed through the throat piece 24 into the holder until it abuts a thin wire 24a at the inner end of the holder. The cigarette will then seal against the internal peripheral edges of the discs 22. The discs 22 may be replaced by discs having a different internal diameter to accommodate cigarettes of a different external diameter. The tubular necks 20 open at their lower ends into circular smoke ducts 26 which extend down through the head 18 and open at the bottom surface of the head into a ring of smoke ports formed in a lapped lower surface of an annular raised portion 27 on the underside of the head 18. The head 18 is continuously rotated in an anticlockwise direction as seen from above over the top of the wall of the chamber 16 at a rate of one revolution per minute by means of an electric motor 28 through a worm and wheel 25:1 reduction gear 29 and a shaft 30 which extends up through bearings 31 in the bottom wall of the chamber 16 and in a fixed turret 32 and is rigidly fixed to a disc 32a to which the head 18 is screwed.

The shaft 30 forms itself the output member of a clutch through which the shaft is driven from the worm wheel of the reduction gear 29. The input member of this clutch is formed by a cup shaped part 33 which is rigidly fixed concentrically to the worm wheel and carries a spring loaded roller 34 which is urged into an axially extending keyway 35 in the shaft 30 to engage the clutch.

The spring which urges the roller 34 into the keyway 35 is sufficiently strong to maintain the clutch engaged during normal rotation of the head 18. However, the roller 34 will ride out of the keyway 35 causing disengagement of the clutch in the event of the head 18 meeting an obstruction or being held or rotated by hand at a speed different from that at which it is driven. When the clutch is disengaged the machine is automatically rendered inoperative by means of a reed switch 36 which is mounted on a dish 37 rigidly fixed to the cup shaped part 33. The switch 36 is controlled by means of a magnet 38 which is carried on an arm 39 projecting outwards from a collar 40 which is rigidly clamped around and rotates with the shaft 30. When and only when the clutch is engaged, the magnet 38 overlies and operates the switch 36 and the resulting signal is transmitted to the stationary part of the machine through spring loaded brushes 41 which rub over carbon rings 42 extending around the base of the tray 37.

As the head 18 rotates the annular raised portion 27 sweeps over and seals against two stationary slide surfaces. The first slide surface is formed by a pad 43 of polytetrafluoroethylene stuck on the top of a flanged tube 44 which extends down through the bottom wall of the chamber 16 and is supported so that the pad 43 is urged resiliently upwards into engagement with the raised portion 27 by a stainless steel diaphragm 45. The tube 44 is sheathed in a sleeve the lower end of which is formed as a chamfered spigot 46 which is coupled by a flexible pipe 47 to a separate control unit (not shown) containing a vacuum system and other controls for the machine. The pipe incorporates one or more extraction vessels containing absorbent material to filter out constituents of tobacco smoke.

An aperture forming a vacuum port 48 is formed through the centre of the pad 43 in register with the interior of the tube 44 and with the ring of smoke ports. The vacuum port 48 is elongated in the circumferential direction of the ring of smoke ports as shown in Figure 1. As the head 18 rotates, the smoke ports in turn come into register with the vacuum port 48 and for a period in which the whole of a smoke port is in communication with the vacuum port, a shut-off valve in the pipe 47 opens and applies a vacuum to the corresponding holder 19 to draw air and smoke through a cigarette in the holder and down through the pipe 47. The shut-off valve in the pipe 47 is opened and closed under the control of a pair of snap action cams 49 which are mounted on the same shaft as the worm of the reduction gear 29 and therefore rotate at twenty five times the speed of the head 18, that is one revolution per smoking cycle as there are twenty five holders 19. The cams are followed by followers 50 which operate electrical switches and hence control the shut-off valve which is solenoid operated. The angular positions of the cams 49 relatively to one another can be adjusted and in this way the puff time may be readily set, within limits, to any predetermined value. In this machine vacuum is applied to each holder in turn for a period of two seconds so that a two second puff is taken from each cigarette each minute. For the rest of the fifty-eight seconds the cigarette smoulders whilst the corresponding smoke port is in communication with the interior of the chamber 16 and hence with the atmosphere through a combined drain and vent 50a in the floor of the chamber 16. In this case "open smoking" is provided but the machine may be converted to "closed smoking", if desired, by providing a complete supported ring of p.t.f.e. in which the two ports 48 and 67 are provided. The smoke ports would then never open into the chamber 16. The switch 36 acts in series with the cam controlled switches such that when the clutch through which the shaft 30 is driven is not engaged the shut-off valve in the pipe 47 cannot be opened thus preventing a rapid succession of puffs being taken from a cigarette situated in the smoking position.

The pneumatic system of the control unit is shown in Figure 6. The circuit includes an electrically driven vacuum pump 51 connected through a vee-port valve 60 to a differential flow-controller 52 which maintains a steady gas flow in the system, the actual flow rate being controlled by means of a vee-port valve 59.

The valve 60 is used to adjust the system to the predetermined vacuum. The flow controller 52 is in turn connected through a flowmeter 53 to a solenoid operated relief and smoking valves 54 and 55, the valve 55 being previously referred to as the shut-off valve in the pipe 47. A safety filter 56 is provided in the line 47 upstream of the valve 55. The low pressure in the circuit is measured by a gauge 57 and the reading is maintained substantially constant since one of the valves 54 and 55 is always open when the other is closed. Thus during a two seconds puff the valve 55 is open and the valve 54 is closed and between puffs the valve 54 is open and the valve 55 is closed. A further vee port valve 58 upstream of valve 54

balances any restriction in the air flow which may be caused by any particular smoke collection unit and thereby a continuously steady reading is maintained on the flowmeter 53. The puff time and flow rate determine the actual puff volume.

The machine has provision during continuous operation for automatic ejection of a smoked cigarette butt from its holder 19 and for the recharging of the holder with a new cigarette. Initially the holders are charged by hand but thereafter when a cigarette has burned down to a predetermined butt length, this fact is sensed by a thermocouple 61 which responds to the heat radiated from the glowing tip of a passing cigarette only when the glowing tip is immediately adjacent to the element 61. When it responds the element 61 sends a signal along a line 62 to the control unit thus priming and operating an ejection mechanism. The ejection mechanism includes a stationary slide surface formed by a polytetrafluoroethylene pad 63 which is stuck on a flanged tube 64 supported by a stainless steel bellows 65 within the chamber 16 similarly to the parts 43, 44 and 45. The lower end of the tube 64 is coupled to a pipe 66 which leads through a shut-off valve to a source of compressed air in the control unit. Within the centre of the pad 63 is a central circular hole 67 forming a pressure port which is in register with the ring of smoke ports in the head and is therefore successively brought into communication with the holders 19 as the head 18 rotates. A ring of part spherical cam surfaces 68 is mounted on the underside of the head 18 and as the head rotates the cams 68 successively depress rollers 69 and 70 and operate corresponding micro-switches 71 and 72. The first time that the micro-switch 72 is operated after response of the element 61 causes the switch 72 to trigger the ejection mechanism by opening the valve in the pipe 66 and causing a blast of air to be supplied through the tube 64 to the holder 19 which carries the butt which causes the element 61 to respond, when the smoke port leading to that holder 19 next comes into register with the pressure port 67. The blast of air causes the butt to be ejected from the holder 19 through a chute into a receptacle containing water or solid carbon dioxide where the butt is extinguished.

The empty holder is then charged automatically with a new cigarette 25 from a hopper 73. The cigarettes 25 in the hopper 73 drop down a guide channel 74 to a charging station 75 which may be supplied with compressed air, from the same source as that from which the pipe 66 is supplied, under the control of the solenoid operated valve 76. A charging operation is primed as a result of the signal received from the element 61 and upon operation of the micro-switch 71 when the holder which previously carried the butt causing response of the element 61 reaches a position in register with the loading station 75, the switch 71 triggers the loading mechanism so that the valve 76 opens and the new cigarette 25 is blown along the station 75 into the holder to recharge it.

It will be seen from Figure 1 that the pressure port 67 is midway between two smoke ducts 26 when a holder is in register with the charging station 75. It follows that the source of compressed air can never be called upon to provide air pulses for butt ejection and cigarette loading simultaneously.

The newly charged cigarette is lit as soon as the corresponding holder reaches the smoking position. Mounted on an adjustable bracket 77 at the smoking position is a ceramic gas burner 78 which is continuously supplied with gas through a pipe 79. The shape and disposition of the outlet nozzles of the burner 78 and its aeration are such that it burns continuously with a substantially planar flame 80, the flame being tangential to the pitch circle traced out by the tips of new cigarettes. As a puff is taken at the smoking position through the new cigarette the tip of the cigarette is just touching the flame 80 and the cigarette is lit. In subsequent revolutions of the head after the cigarette has at least smouldered for one revolution, the tip of the cigarette will be spaced sufficiently far from the flame 80 to be substantially unaffected by the heat of the flame.

The electronic circuit controlling the ejection and recharging mechanisms is illustrated in Figure 7. Upon response of the thermocouple 61 a signal is passed through D.C. coupled amplifier 81 and a Schmitt trigger 82 to a relay amplifier and relay 83 which, if energised causes contacts 84 of relay 83 to close, starting a 0.75 second short duration timer 85. If, while this timer is still operating, the ejection micro-switch 72 is operated and closed, the signal is passed to another 0.3 second short duration timer 86 which, for the 0.3 second period energises a relay amplifier and relay 87. Operation of this relay closes the switch 88 and energises an ejection slave relay 89 which in turn closes switches 90 and 91. Closure of the switch 91 causes the solenoid operated valve in the pipe 66 to open and allows a pulse of compressed air to be passed up through the pipe 66 to eject the butt to be ejected from the holder 19. At the end of the 0.3 second period when the timer 86 stops, the switches 88, 90 and 91 reopen and the shut-off valve in the pipe 66 recloses. When the switch 90 closes it energises a uniselector 92 which starts one or other of four long duration timers 93. The purpose of having a bank of four timers 93 is that at any one time the element 61 may have

responded up to four times before the holder carrying the butt causing the first response may have reached the charging station 75 and the circuit must be able to memorise the requirement of up to four holders requiring recharging with a new cigarette. When one of the timers 93 stops, it actuates an Eccles Jordan circuit 94 which in turn passes a signal through a pulse detector and amplifier 95 to start a 0.75 second short duration timer 96. If during the operation of this timer 96 the charging micro-switch 71 closes a signal is passed to a further 0.3 second short duration timer 97 which energises a relay amplifier and relay 98. This relay in turn closes a switch 99 which energises a charging slave relay 100. Energisation of the slave relay closes switch contacts 101, which cause openings of the valve 76 for 0.3 seconds until the timer 97 stops, and thus provides a 0.3 second air blast to blow a fresh cigarette along the charging station 75 into the holder in register with the station.

The machine illustrated in Figures 8 to 15 comprises a base frame 110 which is mounted on a base board 111. A circular smoking head 112 is mounted on top of the frame 110 and is continuously rotated in a clockwise direction as seen from above in use by a motor 113 through a spindle 114 which passes up through the frame 110 through a seal 115. The head 112 is slidable onto the spindle 114 and is keyed to it, the weight of the head 112 being supported during the rotation by means of three carbon pads 116, 117 and 118, and a carbon ring 119, all of which form stationary slide surfaces.

A ring of 30 equiangularly spaced cigarette holders 120 are screwed into the head 112 and the interiors of the holders communicate with separate smoke ducts 121 which open as smoke ports 122 in the lower surface of the head. Each of the holders 120 incorporates in its entrance a flexible annular rubber disc 123 through which a cigarette 124 may be pushed into the holder 120, the washer 123 then forming a seal against the cigarette.

A central aperture 125 in the pad 116 forms a vacuum port and is in register with the circle of smoke ports 122. The vacuum port 125 communicates through a vacuum duct 126 to a modified Monopump (Registered Trade Mark) 127 which is driven by an electric motor 128 and continuously evacuates the duct 126. The head 112 is rotated at a rate of one revolution per minute and as each smoke port 122 passes over the vacuum port 125 in turn, a two second puff is taken through a lighted cigarette in the corresponding holder. The smoke from all the cigarettes is sucked through the Monopump 127 and fed to a gas distribution system. Between puffs the smoke ports open into a chamber 130a, provided with vents 130b, formed between the head 112 and base 110 to enable the cigarettes to smoulder freely at atmospheric pressure.

A unitary ring of thirty animal cages 131 are, except for separate removable front panels 132, fabricated as a unitary structure from plastics material with a duct ring 134. The duct ring has an inner frustoconical surface which rests on a complementary frustoconical surface at the edge of the head 112. A glass plate 133 which overlies the cages and forms an ashtray is mounted with its inner peripheral edge 135 resting on an annular shoulder 136 at the edge of the head 112. In this way the plate 133 and structure of cages can be readily lifted off the head and replaced and, when the head is rotated, they will rotate with the head.

Each cage 131 is divided by a baffle 137 into a body compartment 138 and a nose compartment 139. The baffle 137 is formed with a central aperture 140 so that when an animal such as a hamster 141 is confined within the cage 131, its nose will be caused to extend through the aperture 140 into the compartment 139.

The duct plate 134 is provided with a ring of similar gas and exhaust ducts 142 and 143 in its conical surface, one gas duct and one exhaust duct leading into the nose compartment 139 of each cage. When the cage structure is correctly mounted on the head 112, each gas duct 142 in the duct plate 134 communicates with a corresponding gas duct 142a in the conical surface of the head and is sealed to it by a flexible washer 144. Similarly each exhaust duct 143 in the duct plate 134 will communicate with and be sealed to a corresponding exhaust duct 143a in the head. The gas ducts and exhaust ducts 142a and 143a in the head open respectively into inner and outer concentric rings of ports in an annular surface 146 which sweeps over the carbon ring 119. The ports at the ends of the gas ducts 142a are in register with a discontinuous inner circular channel which is divided by lands into slots 147, 148 and 149 with which each port remains in communication with for periods of fifty four seconds, four seconds and two seconds, respectively, during each revolution. It will be appreciated that the radius of each port and the width of each land is such that a port moves into communication with the next slot immediately after leaving a previous slot. In a similar manner the ports at the ends of the exhaust ducts 143a are in register with a discontinuous outer circular channel 150 which is broken by only one land 151. An inner tubular collector 152 extends around beneath the frame 110 and is connected to the slot 147 at intervals by connections 153. There is a similar outer tubular collector 154 which is connected at intervals to the slot 150 through

connectors 155. The collectors 152 and 154 are coupled to the gas distribution system.

The gas distribution system and the arrangement of the slots in the carbon ring 119 provide a wide variety of experiments to be conducted. They allow smoke or air polluted with smoke, aerosols, or dust, to be supplied to the nose compartments 139 of the cages for chosen periods of time, and for the cages to be flushed out with fresh air. The essential controls for the system are two manually rotatable spindles 156 and 157 which control separate carbon vane valves 158 and 159 mounted in a valve block 160 secured to the bottom of the frame 110. The spindles also control air selectors simultaneously with the operation of the carbon vane valves. The valve 159 allows the passage of smoke, airborne aerosol, or airborne dust, to pass to the upper valve 158 which directs the gas to one or other of the slots 147, 148 or 149, the former through the collector 152.

The operation of the gas distribution system is as follows. An air blower 161 draws air through a filter 162 and supplies it through a pressure regulator 163 and flowmeter 164 to the upper air selector bank 165 which is controlled synchronously with the upper carbon vane valve 158. The spindle 156 has two positions spaced 90 apart and the spindle 157 has three positions, a central position, and anticlockwise and clockwise positions displaced 90 degrees from the central position. When the upper spindle 156 is in its anticlockwise position, polluted gases reaching the vane valve 158 through a line 166 are directed through a duct 167 to the four second slot 148 and through a line 174 to the collector tube 152 and hence to the fifty four second slot 147. At the same time the air reaching the air selector bank 165 is directed through lines 168 and 169 to the lower air selector bank 170. If the upper spindle 156 is in its anticlockwise position the gas reaching the valve 158 through the line 166 will be directed along a duct 171 which leads to the two second slot 149. At the same time air reaching the upper air selector bank 165 will be directed along a pipe 172 and a duct 173 directly into the fifty four second slot 147.

When the lower spindle 157 is in its central position, and this is the most usual position of operation, with the machine smoking cigarette, smoke will reach the lower carbon vane valve 159 through a line 176 from the Monopump (Registered Trade Mark) 127 and the smoke will pass along the line 166. At the same time the lower air selector bank 170, if receiving air along the line 169 will direct this air along a line 177 into the line 166. When the lower spindle 157 is turned in a clockwise direction, air received by the lower air selector bank 170 will be directed along a line 178 through a dust injector 179 and the dust-polluted air will pass through the carbon vane valve 159 and into the line 166. Similarly, when the lower spindle 157 is turned to its anti-clockwise position, air received at the air selector bank 170 will be directed along a line 180 through an aerosol injector 181 and the aerosol-polluted air will pass through the valve 159 into the line 166.

It will be appreciated that dust- and aerosol-polluted air can only be injected simultaneously into the four and fifty four second slots because it is only this configuration of the upper carbon vane valve and air selector bank that air is supplied to the lower air selector bank for use in carrying the dust or aerosol back to the upper valve 158. However in practice this is quite sufficient.

A suction blower 182 continually draws air from the collector 154, and hence polluted air from the cages, through an electrostatic filter 183, a cotton filter 184, and a flowmeter 185.

Although the machine may be used for inhalation experiments with dust- and aerosol-polluted air which is injected into the cages by the gas distribution system through the inner discontinuous ring of slots, and the gas ducts 142 and 142a without the need for cigarette smoking, the more usual use of the machine is either to collect smoke condensate, through a duct 130 otherwise sealed by a cap 129, for painting experiments, or for inhalation experiments in which smoke or smoke-polluted air, is fed to the animals 141 in the cages 131. In the former case when the machine is required for analytical work and condensate production, the Monopump is removed and the opening 126 blanked off with a sealing plate. A vacuum is applied to the trapping device, e.g. cold trap and connected to the duct 130.

There are two smoke inhalation experiments which are proving extremely useful.

The first experiment is known as "direct smoking" and involves inhalation of pure fresh smoke by the animals for a short period in each cycle. For the rest of the period they breathe fresh air. Direct smoking is achieved by setting the upper and lower spindles 156 and 157 in their clockwise and central positions respectively. In this configuration smoke is directed through the lines 176 and 166 to the duct 171 and hence into the second slot 149. Nothing is directed to the four second slot 148 but fresh air is directed through the line 172 into the fifty four second slot 147. Each animal therefore receives pure smoke for two seconds in every minute followed by four seconds in which no gas is received and fifty four seconds in which fresh air is received. Throughout the whole cycle air is drawn from the cages through the exhaust ducts 143 and 143a, the outer discontinuous slot 150, and the collector 154.

The second experiment is known as "indirect smoking" for this experiment the lower spindle 157 is set in its central position and the upper spindle 156 is set in its anticlock-

wise position, in this configuration smoke is directed along the lines 176 and 166 where it is mixed with air directed along the lines 168, 169 and 177. The mixture of fresh smoke and air is directed by the valve 158 through the ducts 167 and 174 and collector 152 into the four second slot 148 and the fifty four second slot 147. The animals therefore receive a supply of smoke laden air for fifty eight seconds in every minute.

A carbon vane valve 209 is included in the line 176 and, upon operation, directs the smoke drawn by the pump 172 into a branch line 210 for sample analysis for a period of 2 seconds before automatically reverting to its straight through position. In this way a sample can be taken quickly without disturbing any of the experimental control settings.

When the machine is to be used for smoking cigarettes to produce smoke, the holders 120 are loaded with cigarettes 124, the butts of smoked cigarettes are ejected, and the holders are recharged with new cigarettes all automatically. The butt sensing and cigarette charging and lighting devices are supported from an overlying carrier 206.

The butt sensing device is positioned at the angular position marked S and consists of a supporting bracket 186 which is mounted on the carrier and carries at its lower end a cantilevered rod 187. Freely rotatably mounted on this rod 187 are inner and outer coaxial tubes 188 and 189. The inner tube 188 carries at one end a switch contact 190 and at the other end a rider 191 in a position to be engaged by the ring of holders 120. The outer tube 189 carries at one end a switch contact 192 and at the other end a rider 193 in a position to ride over the cigarettes 124 adjacent to the holder 120. The riders 191 and 193 act as counterweights and tend to rock the tubes 188 and 189 so that the riders drop to the lowermost positions. When the riders 191 and 193 are in axial alignment with one another in the lowermost position or otherwise the switch contacts 190 and 192 are separated. As the head 112 rotates, the cigarettes in their holders successively pass the butt sensing device and the riders 191 and 193 ride at the same time over the holders 120 and the cigarettes 124 thus maintaining the switch contacts 190 and 192 apart. However when a cigarette has burnt down to a short butt length the rider 191 will continue to rider over the holders 120 but the rider 193 will brush through the ash at the burning tip of a cigarette and fail to be lifted. This will cause relative rotation between the tubes 188 and 189 and will bring the switch contacts 190 and 192 together completing an electrical circuit and producing a signal. As the holder and cigarette butt, which caused the butt sensing device to be actuated, moves on to the angular position E, the signal causes a solenoid operated valve to open allowing a pulse of air pressure to pass through a duct in the base 110 similar to the duct 126, through to a central aperture 194, forming a pressure port, in the carbon pad 118. At this time the port at the end of the smoke duct leading to the holder carrying the butt to be ejected will be in register with the pressure port 194 and the pulse of air pressure will be directed to the holder and will blow the burnt cigarette butt out of the holder.

A new cigarette charging device is positioned at the angular position C. The charging device consists of a hopper 195 from the bottom of which cigarettes are discharged between rollers 196 positively driven by a motor 197, to a charging station 198 where they are pushed by an electro-pneumatic piston into an empty holder 120 in register with the angular position C. The device recognises an empty holder photo-electrically by means of a sensing mechanism supported from the carrier 206. This consists of an annular dish 199 having in its side wall a number of slots 200, one corresponding to each holder 120. The dish 199 is rotatable on a spindle 201 and is urged downwards by a spring 202 so that a disc 203, screwed to the bottom of the dish, lies against and is keyed by projections 204 to a disc 205 which is screwed to the head 112. In this way the dish 199 rotates with the head and the slots 200 are in alignment with the holders 120. A stationary lamp 207 shines through each slot 200 as it passes the position C. If the corresponding holder is empty, the light shines on a photodiode 208 which produces a signal to trigger the charging mechanism. If the holder is not empty, the cigarette in the holder interrupts the light beam and the photodiode 208 is not energised.

The new cigarette is lit as it reaches the angular position L, that is the smoking position where a puff is taken through the cigarette. At the position L a continuously burning flame is situated. The flame has a thin substantially planar configuration and is positioned at a tangent to the pitch circle traced out by the tips of fresh cigarettes so that a new cigarette will be lit by the flame but in subsequent cycles the flame will not significantly heat the tip of the burning cigarette as the cigarette passes the position L.

WHAT WE CLAIM IS:—

1. A cigarette smoking machine comprising a smoking head which is provided with a ring of cigarette holders for supporting cigarettes so that they extend substantially radially outwards from the head and which is continuously rotated about a vertical axis to bring a series of smoke ducts in the head, one in communication with the interior of each holder, into register with a vacuum port to which vacuum can be applied to draw a puff of air through each cigarette mounted in the holders in turn.

2. A machine according to claim 1, in

which the smoke ducts all open into an annular surface of the head, this surface sweeping over a stationary slide surface in which the vacuum port is formed.

3. A machine according to claim 2, which also includes a cigarette butt ejecting mechanism comprising a second stationary slide surface over which the annular surface sweeps and which is formed with a pressure port, the pressure port being successively brought into communication with each smoke duct and being arranged to be supplied with pulses of air pressure whereby the butts of burnt cigarettes can be ejected from the holders by air pressure pulses applied to the corresponding smoke ducts through the pressure port.

4. A machine according to claim 3, in which the butt ejecting mechanism also includes a butt length sensing element which is mounted adjacent to the ring of holders and which responds to a passing cigarette butt if the cigarette has burned down to a predetermined length, the element then triggering means for supplying a pulse of air pressure to the pressure port when the smoke duct leading to the holder carrying that cigarette butt is next in communication with the pressure port so that the cigarette butt is ejected from its holder.

5. A machine according to any one of the preceding claims, incorporating a gas burning lighter for automatically lighting fresh cigarettes fitted to the holders, the lighter providing a substantially vertical planar flame the plane of which is tangential to, and radially spaced outwards just beyond, the pitch circle traced out by the tips of new cigarettes fitted to the holders.

6. A machine according to any one of the preceding claims, in which the head rotates over a chamber in which the vacuum port is provided, the smoke ducts opening into the chamber through substantially the whole of the period in which they are not in communication with the vacuum port.

7. A machine according to any one of the preceding claims, in which each holder incorporates a flexible annular disc through which a cigarette is a push fit when inserted into the holder to provide a seal around the cigarette in the holder.

8. A machine according to claim 7, in which the annular disc is readily removable for replacement by a disc having at least a different internal diameter to accommodate a cigarette of a different diameter.

9. A machine according to any one of the preceding claims, including means for controlling the vacuum supplied to the vacuum port so that the vacuum is only supplied during the period in which the whole cross-sectional area of a smoke duct is in communication with a constant area of the vacuum port.

10. A machine according to claim 9, in which the control means includes snap action cams which are rotated synchronously with the smoking head and control the opening and closing of a valve in a conduit through which vacuum is supplied to the vacuum port.

11. A machine according to any one of the preceding claims, in which the vacuum port is elongated in the direction of relative movement between the head and vacuum port.

12. A machine according to any one of the preceding claims, incorporating a cigarette loading mechanism, the loading mechanism comprising a magazine for cigarettes, and means arranged to be supplied with pulses of air pressure for blowing cigarettes one at a time from the magazine along a guide into an empty holder in register with the guide.

13. A machine according to claim 12, when dependent at least upon claim 3, and including a common compressed air system for both the butt ejecting mechanism and the cigarette loading mechanism, the two mechanisms being so synchronised with rotation of the head that their requirements of air pulses from the common supply system are at all times out of phase with one another.

14. A machine according to any one of the preceding claims, in which a transmission through which the head is rotatably driven incorporates a spring loaded clutch which transmits the drive to the head but which can be overridden upon subjection to an excessive relative torque between its input and output members greater than that necessary to drive the head normally.

15. A machine according to claim 14, in which one of the input and output members of the clutch carries a magnet and the other a reed switch providing overriding electrical control for a valve through which vacuum is suppied to the vacuum port, the magnet being adjacent the reed switch and operating it in such a manner that the valve can be opened at intervals under normal operation only when the clutch is properly engaged.

16. A machine according to any one of claims 1 to 7, further comprising a ring of animal cages which rotate with the head, a series of gas ducts leading one to each cage, and a gas distribution system which is arranged to supply a vacuum to the vacuum port to draw puffs of smoke through each cigarette holder in turn and to distribute the smoke to the gas ducts.

17. A machine according to claim 16, in which the gas distribution system is selectively capable of distributing other gases instead of or in addition to the smoke to the gas ducts.

18. A machine according to claim 16 or claim 17, in which the gas ducts all open into an annular surface of the head which sweeps over a stationary gas distribution slide surface formed with at least one gas port to which the gas distribution system distributes the smoke and/or other gases and which is suc-

cessively brought into communication with each gas duct in turn.

19. A machine according to any of claims 16 to 18, in which there are a number of exhaust ducts leading one from each cage and opening into an annular surface of the head which sweeps over a stationary gas distribution slide surface formed with at least one exhaust port to which the gas distribution system provides a suction and which is brought into communication with the exhaust ducts to draw smoke or other gases from the cages.

20. A machine according to claim 19 when dependent on claim 18, in which the at least one gas port and the at least one exhaust port, each in the form of a circumferentially extending slot, are both formed in a common gas distribution slide surface.

21. A machine according to any one of claims 16 to 20, in which the ring of animal cages are provided by a unitary plastics assembly which fits over and around the head and which is divided by radial partitions into the separate cages, the gas ducts, and exhaust ducts when provided, extending radially to the periphery of the head where they open into the corresponding cages.

22. A machine according to claim 1, substantially as described with reference to Figures 1 to 7, or to Figures 8 to 15, of the accompanying drawings.

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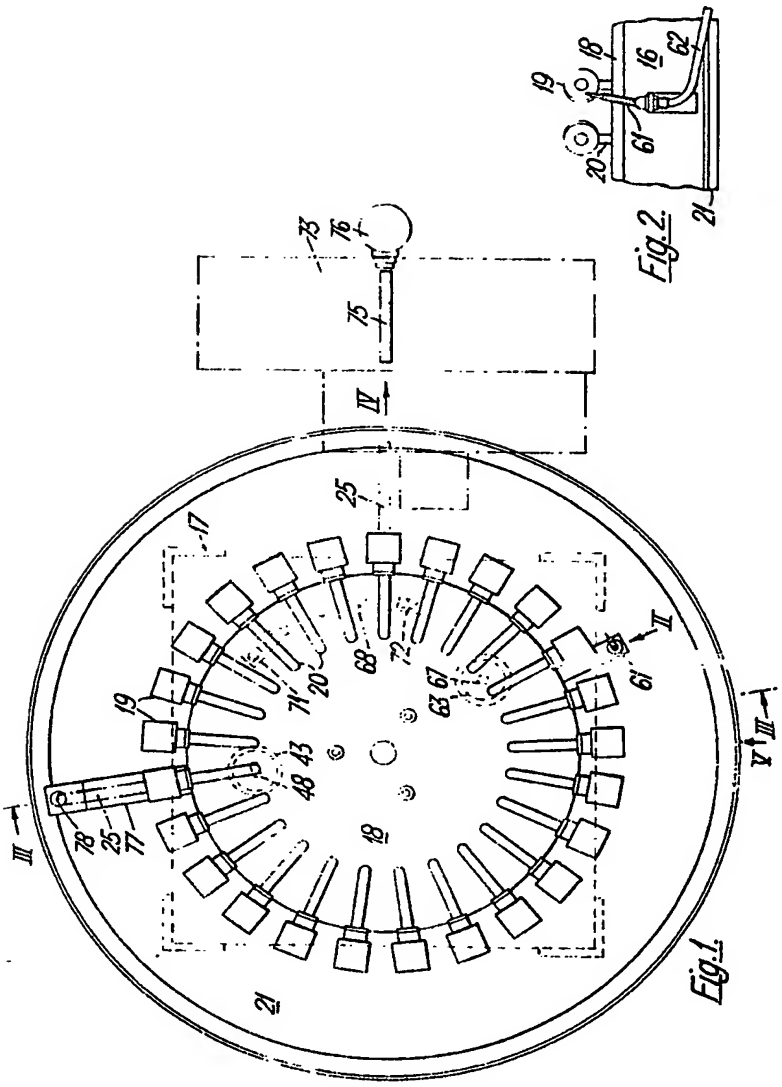

Fig.1

Fig.2

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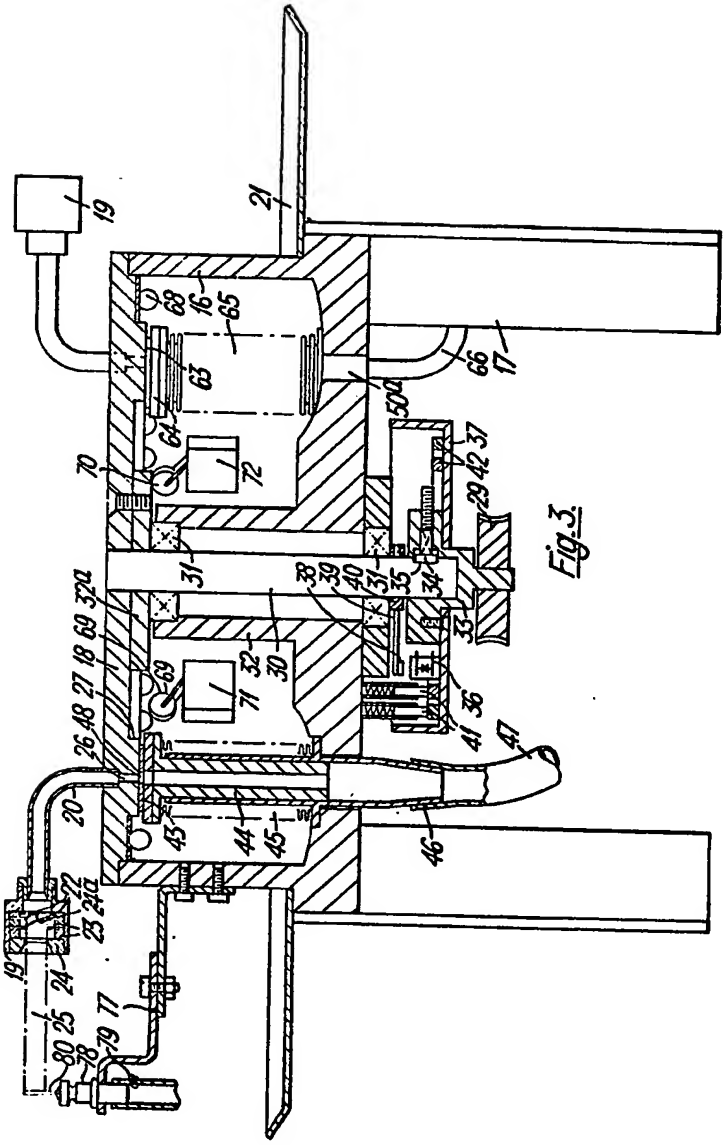

Fig.3.

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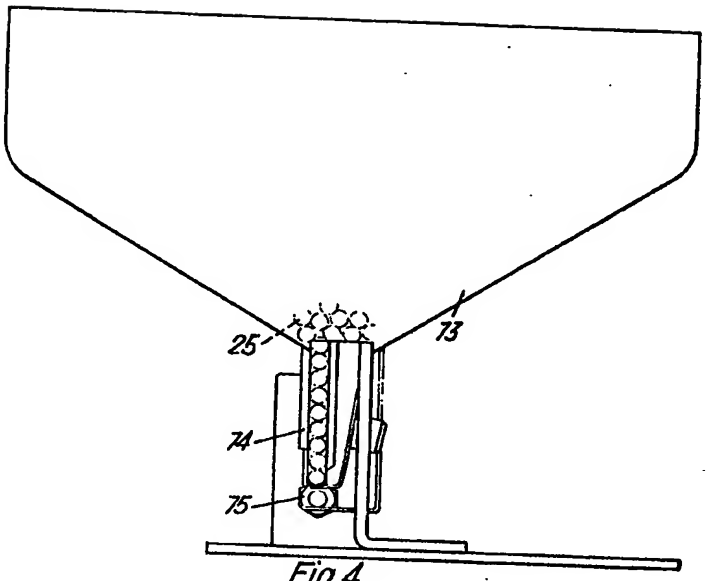

Fig.4.

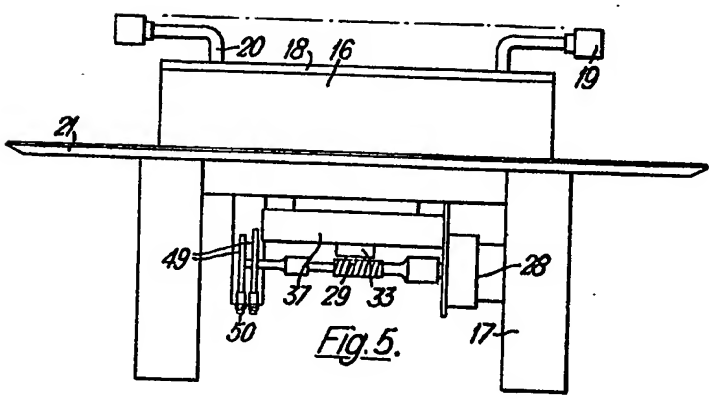

Fig.5.

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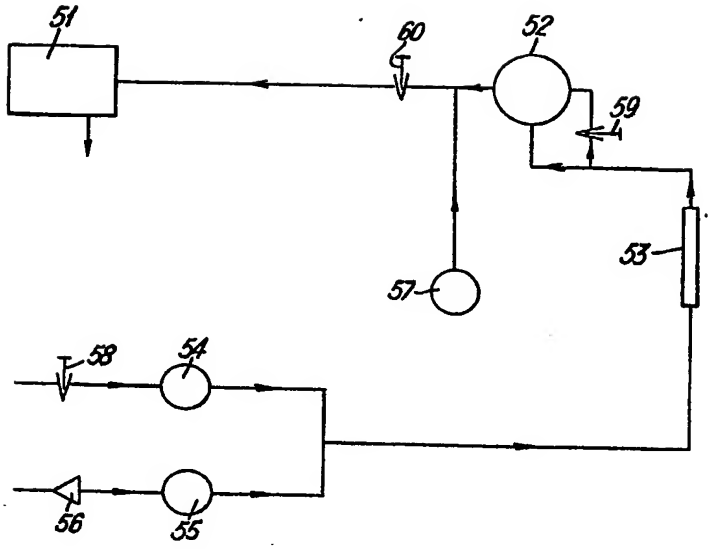

Fig. 6.

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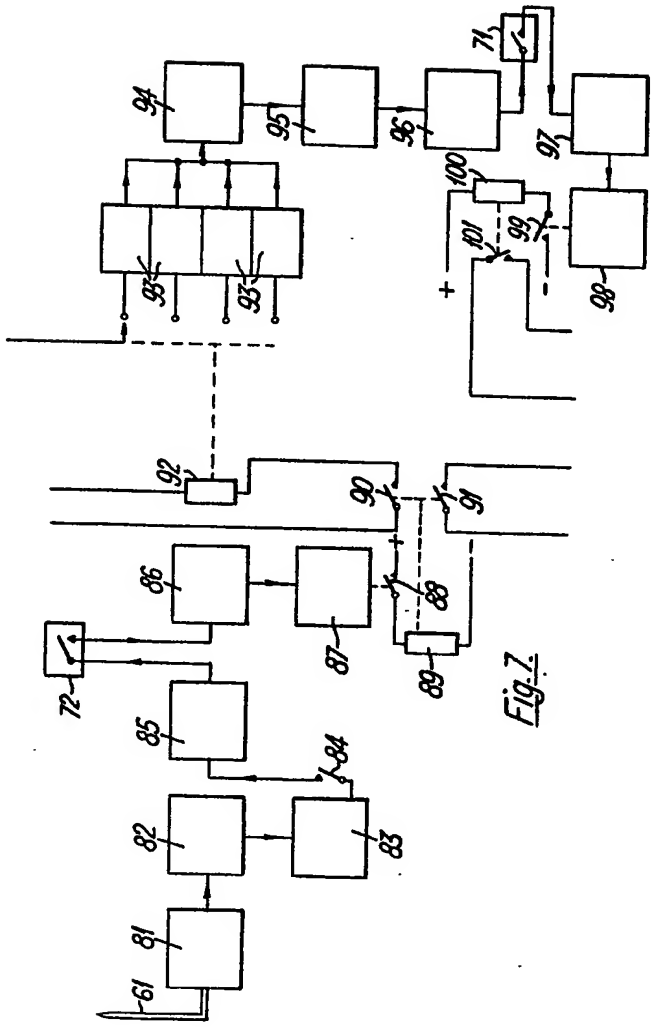

Fig. 7

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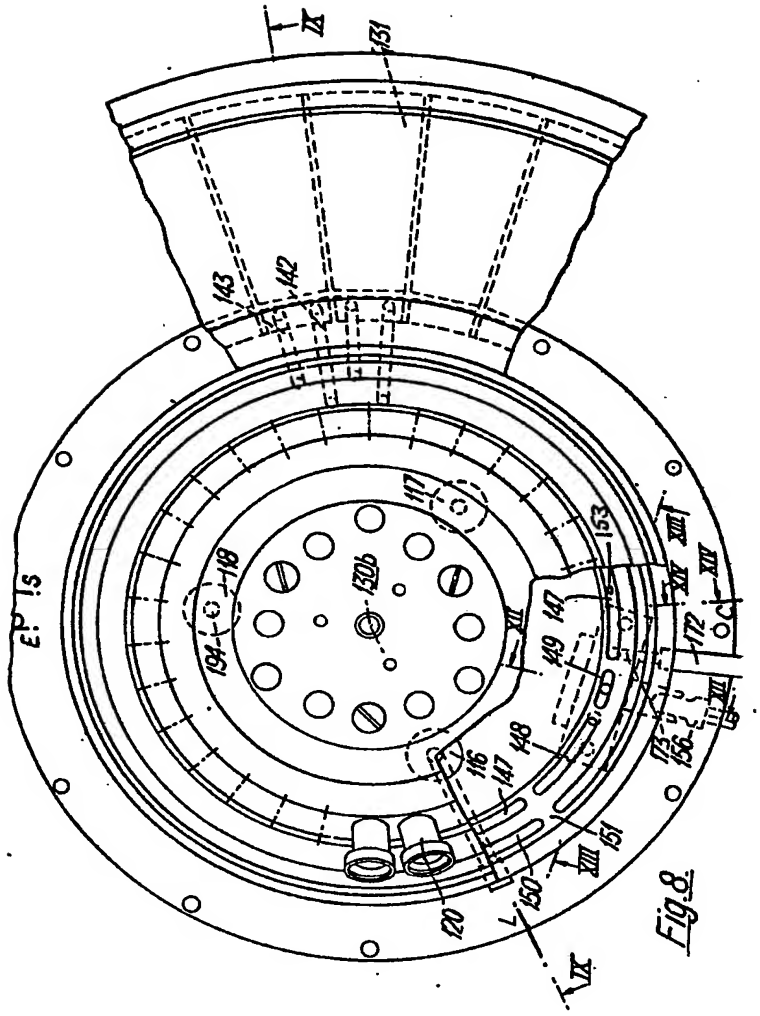

Fig.8

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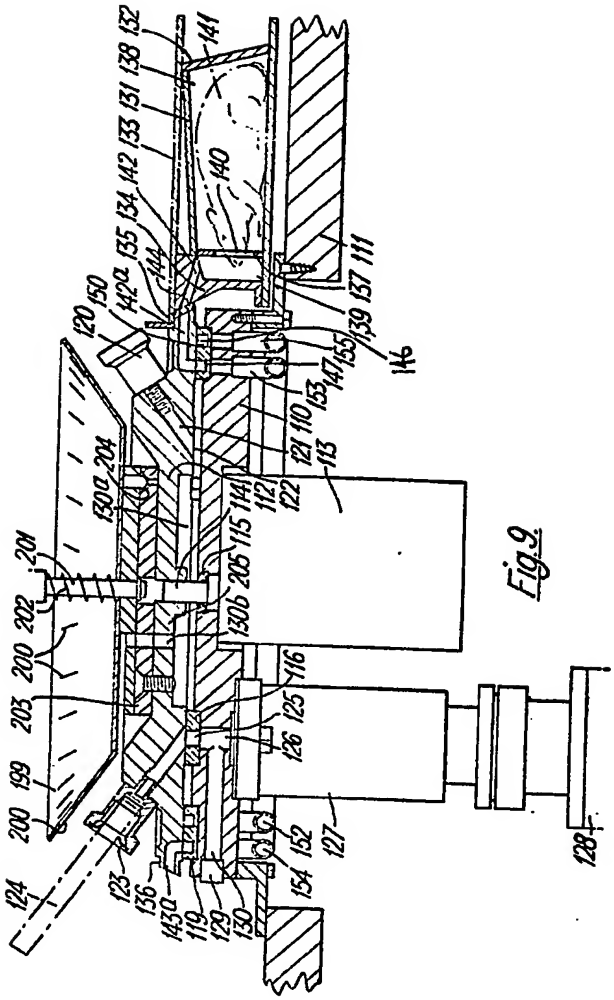

Fig.9

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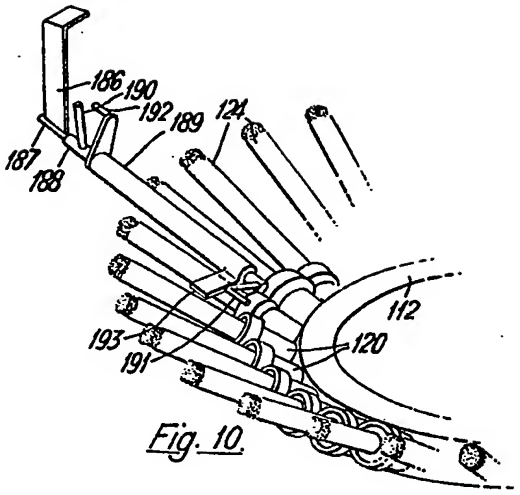

Fig. 10.

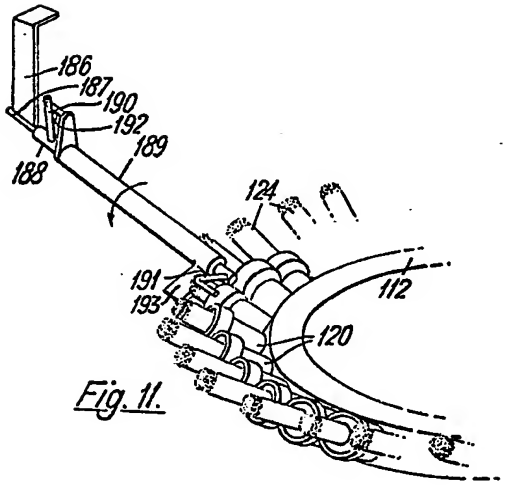

Fig. 11.

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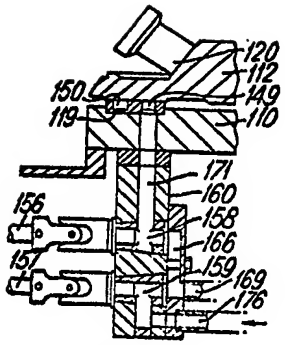

Fig. 12.

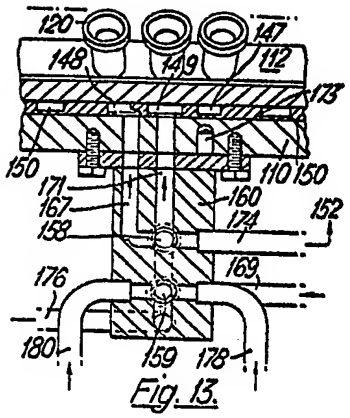

Fig. 13.

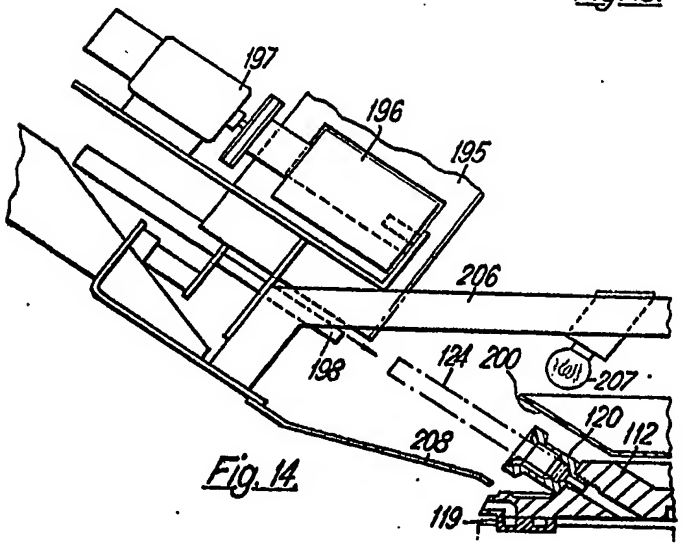

Fig. 14.

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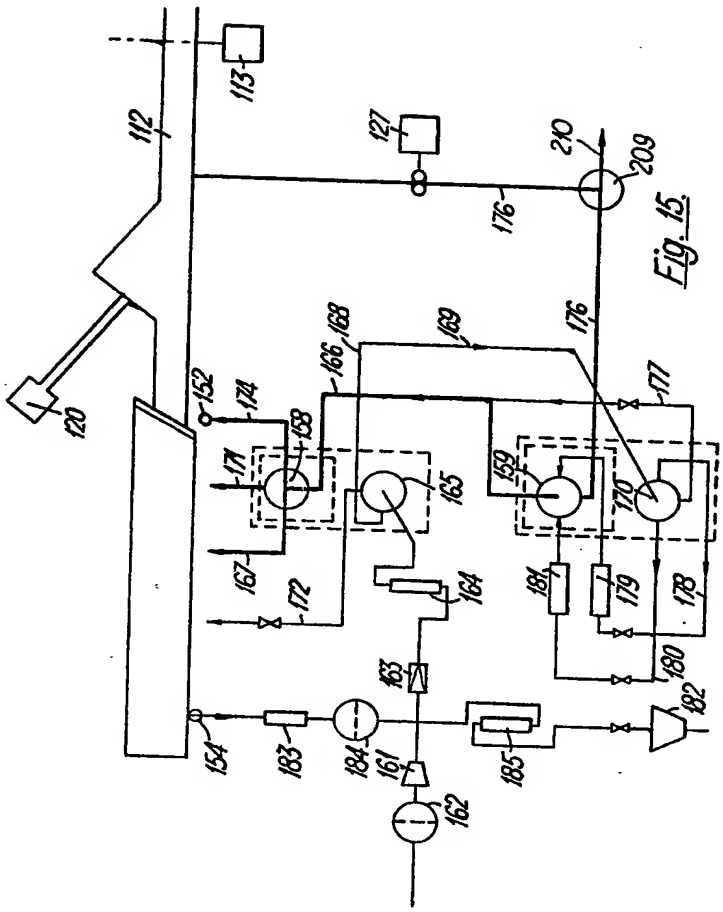

Fig. 15.